FIRE OR OVERHEATING DETECTION SYSTEM

Background of the Invention

Field of the Invention

The present invention relates to a system for detecting fire or overheating.

Description of the Related Art

A variety of different systems and methods for detecting fire or overheating are known. These systems are often used in engine regions, for example, of an aircraft, ship, helicopter, submarine, space shuttle or industrial plant, and more generally in any sensitive region where the risk of fire or overheating exists, for example, in a hold or bunker, train compartment or boiler.

U.S. Patent No. 5 136 278 describes one type of detector that detects local or average overheating. The detector uses a gas which, when it expands owing to the effect of overheating, trips an electrical contact, thereby indicating that a mean temperature of the detector has exceeded a threshold temperature. Metal oxides with an absorbed gas distributed over the entire length of the detector provide, by a degassing principle, a local indication that the temperature exceeds the threshold temperature.

Another type of detector measures the resistance of a material having a negative thermal coefficient ("NTC"). The material may be implemented as a negative thermal coefficient cable. This type of detector is used for detecting local overheating.

Summary of Certain Inventive Aspects

A gas-type detector requires moving parts to be joined together and has, therefore, a complicated, fragile and expensive construction. An NTC-type detector applies the resistance as the sole criterion and is not very robust in fault situations. It is, therefore, an objective to provide a system for detecting fire or overheating that has improved features with respect to construction and robustness.

One inventive aspect involves a system for detecting fire or overheating. The system includes a sensor including at least one material having a resistance with a selected temperature coefficient, wherein the resistance of the material is indicative of a temperature. The system includes further a device connected to the sensor to perform measurements on the at least one material, wherein the device is configured to determine at least one parameter from the measurements and to analyze a dynamic behaviour of the at least one parameter to deduce status information including overheating and malfunction of the sensor.

Another inventive aspect involves a method of detecting fire or overheating. The method performs measurements on at least one material having a resistance with a selected temperature coefficient and included in a sensor that is coupled to a device, wherein the resistance of the material is indicative of a temperature. At least one parameter is determined from the measurements. A dynamic behaviour of the at least one parameter is analyzed to deduce status information including overheating and malfunction of the sensor.

The system proposed has in particular the advantage of carrying out processing operations that take into account fouling situations or failure situations (a short circuit, open circuit, etc.). It also has the advantage of allowing thermal profiles to be determined in real time.

Brief Description of the Drawings

These and other aspects, advantages and novel features of the embodiments described herein will become apparent upon reading the following detailed description and upon reference to the accompanying drawings. In the drawings, same elements have the same reference numerals.

Figure 1 is a schematic representation of one embodiment of a system for detecting fire or overheating;

Figure 2 shows schematic graphs illustrating the resistance of a material with a negative temperature coefficient as a function of temperature and a sensor portion subject to overheating;

Figure 3 shows schematic graphs illustrating the resistance of a nickel

wire as a function of a sensor portion subject to overheating;

Figure 4 shows graphs as a function of a sensor portion subject to overheating, local temperature and mean temperature;

Figure 5 is a graph illustrating a sensor portion subject to overheating as a function of the graphs shown in Figure 4;

Figure 6 is a schematic representation of an equivalent circuit diagram of the sensor; and

Figure 7 is a schematic representation of a measuring and processing device connectable to the sensor.

Detailed Description of Certain Inventive Embodiments

Figure 1 shows a schematic illustration of one embodiment of a system for detecting fire or overheating. In one application, the system may be installed in an automobile, train, aircraft or ship, for example, next to or within an engine, passenger or cargo compartment, to detect a fire or overheating. It is contemplated that the system may be installed at any location where the risk of fire or overheating exists, such as at an industrial site, a power generation or transformer station, a data processing or storage room, or an aircraft engine, in particular a jet engine, passenger or cargo compartment.

The system according to one embodiment comprises a sensor C and a device T connected to the sensor C. The device T measures and processes characteristics obtained from the sensor C. The sensor C comprises a conducting core 2 extending within a sheath 3 that is conducting. For example, the core 2 may extend along a longitudinal axis of the sheath 3 or along an inside of the sheath 3. A material 4 separates the core 2 and the sheath 3 and has a negative temperature coefficient.

The sensor C of the illustrated embodiment further comprises a wire 1 and an insulating material 5 that separates the wire 1 from the sheath 3. In one embodiment, the wire 1 is made of a material having a positive temperature coefficient ("PTC"), for example, a Nickel (Ni) wire, and is, for example, wound around the sheath 3. The wire 1, the core 2 and the sheath 3 are connected to the device T via terminals 1a, 2a and 3a. The whole assembly is placed in an external sheath 6.

Variations in a resistance R_{Ni} of the wire 1 are directly proportional to

variations in the mean temperature of the sensor C. The variation in a resistance R_{NTC} of the material 4 allows local areas of overheating to be detected. For overheating over a given portion of the sensor C, the resistance R_{NTC} of the material 4 varies with temperature, i.e., it decreases exponentially.

The device T performs resistance measurements and determines through these measurements the resistance R_{Ni} of the wire 1 and the resistance R_{NTC} of the material 4. The resistance values obtained are processed to deduce information regarding possible general or local areas of overheating. Further, the device T processes the resistance values to deduce inconsistencies indicative of a malfunction such as short circuits, open circuits, fouling, etc.

For a particular application and under normal operational conditions, the resistance R_{Ni} of the wire 1 normally takes values which, depending on the envisaged application, lie within a given range. This range depends on the parameters of the wire 1, such as length and diameter. For example, for a length of about 1 m, the range extends between a few ohms (e.g., 20 ohms) and a few hundred ohms (e.g., 200 ohms). The device T therefore compares the measured resistance value of the wire 1 with expected maximum and minimum resistance values for that particular application. When the resistance value of the wire 1 lies outside the given range, the device T triggers the transmission of a signal indicative of a malfunction of the sensor C.

Figure 2 shows several schematic graphs illustrating the resistance R_{NTC} of the material 4 having a negative temperature coefficient as a function of a sensor portion α subject to overheating. If $\alpha = 1$, the entire sensor is subject to overheating, and if $\alpha = 0.5$, half of the sensor length is subject to overheating. The graphs are given for two mean temperatures 250°C and 350°C measured on the basis of the resistance variations of the wire 1, and for various ambient temperatures 100°, 150°, 200° and 300°C. As shown in Figure 2, the graphs representing the resistance R_{NTC} for a given ambient temperature and mean temperature terminate in a maximum limiting value $R_{NTCmax1}$, $R_{NTCmax2}$. It is contemplated that a resistance value above the limiting value $R_{NTCmax1}$, $R_{NTCmax2}$ is indicative of a defect or perturbation of the sensor C.

A measured resistance R_{Ni} of the wire 1 is indicative of a given overall

temperature of the sensor C. For that overall temperature a limiting value $R_{NTCmax1}$, $R_{NTCmax2}$ exists at $\alpha = 1$, i.e., when the entire sensor is subject to overheating. The device T compares the measured resistance R_{NTC} with the limiting value $R_{NTCmax1}$, $R_{NTCmax2}$ for the given overall temperature. When the resistance R_{NTC} is greater than this limiting value $R_{NTCmax1}$, $R_{NTCmax2}$ the device T triggers the transmission of a signal indicative of a malfunction of the sensor C.

Figure 3 shows several schematic graphs illustrating the resistance R_{Ni} of a nickel wire as a function of the sensor portion α subject to overheating for several mean temperatures. Corresponding to each resistance value $R_{NTC1,2}$ of the material 4 is a maximum nickel resistance value R_{Nimax1}, R_{Nimax2} at $\alpha = 1$. That is, the resistance R_{NTC} is used to determine a possible value for the resistance R_{Ni}, which has to be within a given range for a particular sensor C. For a given value of the resistance R_{NTC} with a negative temperature coefficient, the device T performs a comparative processing operation to check that the mean temperature corresponding to the nickel resistance R_{Ni} is below a given limiting value R_{Nimax1}, R_{Nimax2} since the mean temperature cannot be higher than the ambient temperature. When this is not the case, the device T triggers the transmission of a warning signal indicative of a malfunction of the sensor C.

The device T also performs a dynamic processing operation by analysing variations in one or more parameters, for example, to indicate overheating or an inconsistency in the measurements. Thus, to determine local overheating or general overheating, the device T compares certain threshold values not to the resistance R_{NTC} of the material 4 and the resistance R_{Ni} of the wire 1 directly, but to differential values of these resistances.

The device T advantageously determines the sensor portion α that is subject to overheating and performs a consistency test on the determination thus made. This includes analysing the variations in $\log(R_{NTC})$ (i.e., the difference between $\log(R_{NTC})$ at time T1 and $\log(R_{NTC})$ at time T0) and the variations in the resistance R_{Ni} of the wire 1 (i.e., the difference between R_{Ni} at time T1 and R_{Ni} at time T0). The parameters that constitute $\log(R_{NTC})$ and the resistance R_{Ni} of the wire 1 are in fact parameters which have been shown to vary linearly with temperature (local temperature and ambient temperature, respectively). Figure 4 illustrates the values of a ratio of the variations of $\log(R_{NTC})$ and R_{Ni} for various values of the sensor portion α subject to

overheating. The ratio values are plotted as a function of the measured local temperatures and mean temperatures.

The ratio of the variations in these two parameters varies with the mean temperature and with the local temperature as a function that depends directly on the sensor portion α that is subject to overheating. In particular, when the local temperature is more than 100°C above the mean temperature of the sensor C the determined curves are asymptotic curves that depend directly on the value of the sensor portion α, but not of the temperature. This allows to conclude what portion of the sensor C is overheated, for example, 50% of the sensor C is overheated.

Similarly, in Figure 5, the asymptotic value taken by the aforementioned ratio has been plotted for various values of α. Thus, the device T determines the value of α that corresponds to the variations in the values of log (R_{NTC}) and R_{Ni} that the device T measures. The device T analyses the consistency of the determined α value and when the α value exceeds the [0,1] range transmits a signal indicative of a failure of the sensor C.

Other ratios of variations could be used. In particular, the ratio of differential values of log(R_{NTC}) and R_{Ni} could be used in the same way, wherein the differential values are calculated on the basis of the values taken by the two parameters log(R_{NTC}) and R_{Ni} at two different measurement times.

Figure 6 is a schematic representation of an equivalent circuit diagram of the sensor C including the terminals 1a, 2a and 3a shown in Figure 1. The circuit diagram includes two resistors R_1 and R_2 connected via an intermediate terminal ZA. A resistor R_f is connected between the terminal ZA and a terminal 3b. The resistor R_f is equal to the resistance R_f of connecting cables that connect the terminals 1a, 2a of the resistors R_1 and R_2 to terminals 1b and 2b, respectively.

A perturbation resistor R_p is also shown connected between the terminals 1a, 2a of the resistors R_1 and R_2. The resistor R_1 corresponds to the resistance R_{Ni} in parallel with R_{p1}, and the resistor R_2 corresponds to the resistance R_{NTC} in parallel with R_{p2}.

The various resistances between the terminals 1b to 3b are measured cyclically using a circuit illustrated in Figure 7. The circuit measures successively the resistance between the terminals 1b and 2b, the resistance between the terminals 1b and 3b and the resistance between the terminals 2b and 3b.

Further, in one embodiment, the circuit determines in succession, the ratio of the voltages $\frac{U_{1b3b}}{U_{2b3b}}$, the ratio of the voltages $\frac{U_{3b2b}}{U_{1b2b}}$ and the ratio $\frac{U_{2b1b}}{U_{3b1b}}$, where U_{kl} denotes the voltage between a terminal k and a terminal l, wherein k and l indicate the terminals 1b, 2b and 3b.

In the illustrated embodiment, the device T of the system comprises a multiplexer M that selects particular terminals of the sensor in order to perform the measurements, and a microprocessor μC that receives outputs from the multiplexer M. In one embodiment, the multiplexer M outputs voltages that may be shaped before input to the microprocessor μC.

The values of the resistances R_{Ni} and R_{NTC} are then determined from the measurements of the resistances between the terminals 1b to 3b. Thus:

$$R_{Ni} = \frac{R_P.R_1}{R_P - R_1}$$

$$R_{NTC} = \frac{R_P.R_2}{R_P - R_2}$$

$$R_{12} = \frac{(R_1 + R_2).R_P}{R_1 + R_2 + R_P} + 2R_f$$

$$R_{23} = \frac{(R_P + R_1).R_2}{R_1 + R_2 + R_P} + 2R_f$$

$$R_{13} = \frac{(R_P + R_2).R_1}{R_1 + R_2 + R_P} + 2R_f$$

This system of equations can be solved in order to deduce therefrom the values of R_{Ni}, R_{NTC} and R_p.

The system of equations is generally not invertible in order to obtain R_f. The value of R_f can be estimated by assuming that R_f obeys a symmetrical model. In this case, the value of R_f, like the value of R_p, is compared with maximum values that demonstrate the existence of fouling at the contacts and therefore indicate a state conducive to potential failures. The perturbations in the measurements may also, where appropriate, be corrected accordingly.

In the general case in which R_p and R_f obey an unsymmetrical model, then R_{Ni} and R_{NTC} cannot be calculated directly. However, by considering R_p and R_f as perturbations introduced on the system, it is possible to estimate and put limits on said values of R_p and R_f, and consequently to detect an abnormal situation.